CS 2110 Lecture 5

Interfaces, subtyping, polymorphism

Coming up

A2 is Released

A1 will be graded soon

Test 1 is Tomorrow (I'll end with what to prep for Test1)

A2 Logistics and Test1 Prep

- Please start A2, Also if you're working alone and haven't talked to me about working with a partner. Please find a partner ASAP
- Test1 Prep and Expectations
  - Exactly the same style of questions as the prelims in the previous years
  - Topics are obviously adapted to what we covered here last week
  - Format is hard to predict exactly

JUnit

- JUnit assertions != Java `assert` statements
  - `assertEquals()`
  - `assertTrue()` / `assertFalse()`
- Argument order: *expected*, then *actual*

- Floating-point is tricky (see comment in A1Test)

Terms So Far

- Java syntax specific
  - this
  - final
  - static
  - main
  - class
  - void
  - public/private/protected
  - Junit Test related terms
  - extends
- Concepts
  - Value/Reference Semantics
  - Primitive/Class Types
  - Specifications/Invariants
  - Constructors/Getters/Setters
  - Scope
  - Casting
  - Testing- Black Box/Glass Box
  - OOP - Inheritance and Polymorphism

Inheritance

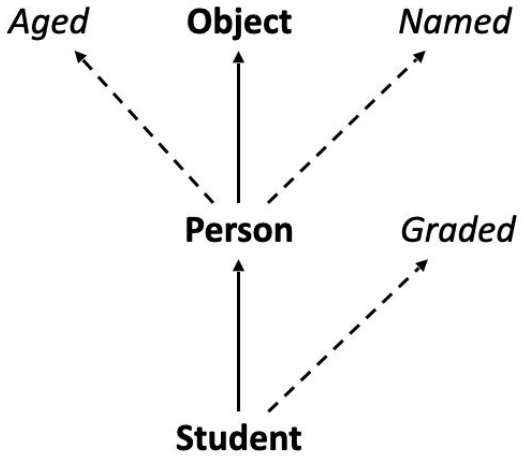
- Inheritance in Java is the method to create a hierarchy between classes by inheriting from other classes.
- It is basically a method to establish relationships between classes.

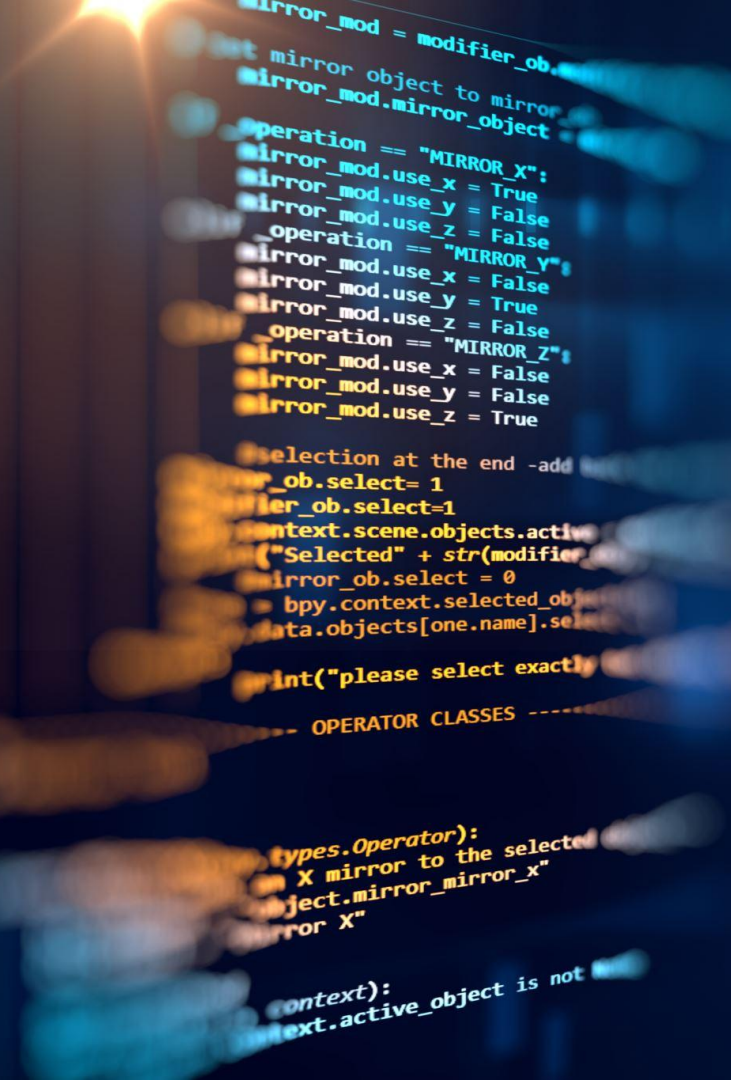
```
public class A {
    // A's fields
    // A's methods
}

public class B extends A {
    // B's fields + A's (public and protected fields)
    // B's methods and A's (public and protected fields)
}
```

Relationships

- Java only supports *single inheritance*
  - Only one superclass
  - Reserve for “is-a” relationship
- Classes may implement multiple interfaces
  - “Can-do” relationship





DRY principle: Don’t repeat yourself

- Duplicated code is not just tedious to write (or copy-paste) the first time
  - To fix a bug in duplicated code, must find all instances
  - Modifications that aren’t repeated everywhere lead to deviation in “common” behavior
- OOP languages can help you avoid duplication

Consequences of this

- Avoid code reduplication
- Subtype Polymorphism, Interface Polymorphism
- Allows for the expression of variations in behaviour

    - Defining inheritance hierarchies is basically a modelling problem

Interface Polymorphism

Interfaces allow us to define polymorphism in a declarative way, unrelated to implementation

What is an interface?

```
public interface Box {
    2 implementations
    public void shift(int dx, int dy);
    2 implementations
    public float ares();
    2 implementations
    public boolean isInsideBox();
}
```

What this looks like in Java

Interfaces are basically like contracts

```
public class Box1 implements Box {

    /**
     * Location of the lower-left corner of this box (point with minimum x-coordinate and minimum
     * y-coordinate).  Non-null.
     */
    private final Point lower;

    /**
     * Location of the upper-right corner of this box (point with maximum x-coordinate and maximum
     * y-coordinate).  Non-null.  Invariant: {@code upper.x >= lower.x AND upper.y >= lower.y}.
     */
    private final Point upper;

    public void shift(int dx, int dy) { /* .... */ }
    public float ares() {  /* .... */ }
    public boolean isInsideBox() {  /* .... */ }
}
```

What this looks like in Java

Here's another way of doing the exact same thing

```
public class Box2 implements Box {

    /**
     * Location of box's centroid.  Non-null.
     */
    private final Point center;

    /**
     * Width of box (in coordinate system units).  Finite and non-negative.
     */
    private final double width;

    /**
     * Height of box (in coordinate system units).  Finite and non-negative.
     */
    private final double height;

    public void shift(int dx, int dy) { /* .... */ }
    public float ares() {  /* .... */ }
    public boolean isInsideBox() {  /* .... */ }
}
```

Polymorphism (SubTyping)

Variations in behavior

- The Interval interface abstracted over state, but both implementations behaved identically. We just saw an example of this.
- Sometimes, behavior specifications leave room for variation
- Example: chess pieces

Chess piece interface

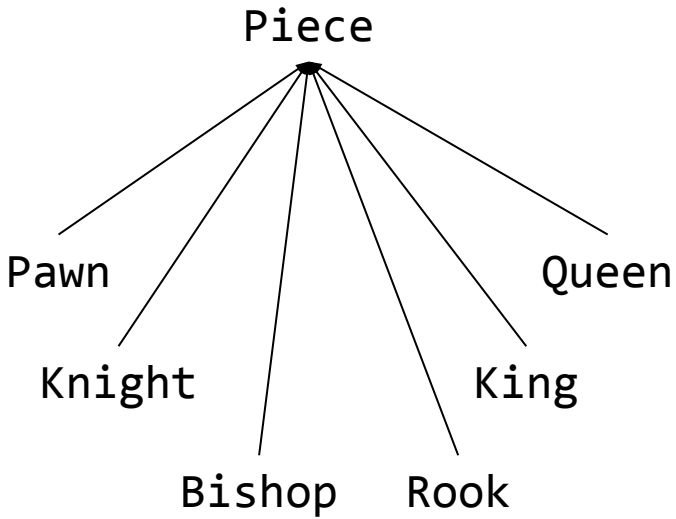
```
public interface Piece {
  /** Return whether this piece is able to move to
   *  location (`dstRow`, `dstCol`) from its current
   *  position, given board config. `board`. */
  boolean legalMove(int dstRow, int dstCol,
                    Board board);
}
```

Chess board interface

```
public interface Board {
  /** Return 0 if position (`row`, `col`) is empty,
   *  1 if occupied by a white piece, 2 if occupied
   *  by a black piece. */
  int playerAt(int row, int col);
}
```

Type hierarchy

- `Pawn   <: Piece`
- `Knight <: Piece`
- `Bishop <: Piece`
- `Rook   <: Piece`
- `Queen  <: Piece`
- `King   <: Piece`



Knight

```
public class Knight
    implements Piece {
  private int row;
  private int col;
  private int player;
  @Override
  public boolean legalMove(
      int dstRow,
      int dstCol,
      Board board) {
    int dx = abs(row-dstRow);
    int dy = abs(col-dstCol);
    return board.playerAt(
        dstRow, dstCol)!=player
        && ((dx==1 && dy==2) ||
            (dx==2 && dy==1));
  }}
```

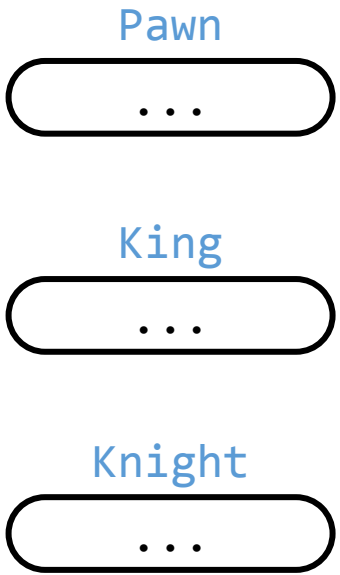
King

```
public class King
    implements Piece {
  private int row;
  private int col;
  private int player;
  private boolean hasMoved;
  @Override
  public boolean legalMove(
      int dstRow
      int dstCol,
      Board board) {
```

```
int dx = abs(row-dstRow);
int dy = abs(col-dstCol);
return board.playerAt(
    dstRow, dstCol)!=player
    && (dx <= 1 && dy <= 1
     || !hasMoved &&
        canCastle(board));
}}
```

Object diagram

```
Piece pickNextPiece() {...}
// ...
Piece p;
while (!gameOver) {
  p = pickNextPiece();
  // assign r, c
  if (p.legalMove(r, c)) {
    // ...
  }
}
```



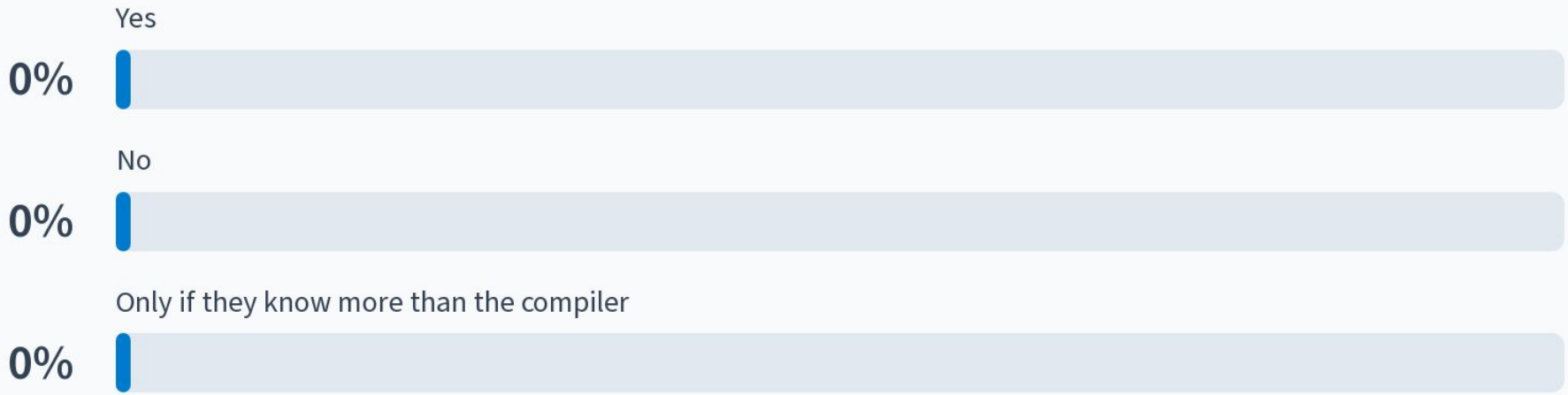
Static vs. dynamic type

- While the program is running, the type of the object referenced by p could change, but it will always be a subtype of Piece

- Static type: types declared for variables & return values, derived for expressions (compile-time)
- Dynamic type: the type of an object being referenced (runtime)

- Behavior is determined by dynamic type
  - "**Dynamic dispatch**"

Should client be able to call `p.canCastle()` when the dynamic type of the object referenced by Piece p is a King?



Compile-time reference rule

- Client can only request behavior supported by the static type

- It is possible to ask about the dynamic type of an object and **cast** the reference so that additional behavior is available, but this is usually not good OOP practice
  - instanceof
  - Example next time: equals()

Commonality beyond interfaces

- Interfaces guarantee *availability* of behaviors
- What if types have similar state? Identical behaviors?
  - Interfaces can't provide fields or method bodies that depend on fields
- **Subclasses** allow a *derived class* to **inherit** fields and method bodies from a *parent class*
  - `class Derived extends Parent {...}`
  - Implies a *subtype* relationship: Derived <: Parent

Piece as a superclass

```
public class Piece {
  private int row;
  private int col;
  private int player;

  public Piece(int row,
      int col, int player) {
    this.row = row;
    this.col = col;
    this.player = player;
}
```

```
  public int player() {
    return player;
  }

  public boolean legalMove(
      int dstRow, int dstCol,
      Board board) {…}
}
```

King as a subclass

```
public class King
    extends Piece {
  private boolean hasMoved;


  public King(int player) {
    super((player==1)?0:7,
          3, player);
    hasMoved = false;
  }
```

```
  @Override
   public boolean legalMove(
       int dstRow
       int dstCol,
       Board board) {…}
}
```

Accessibility

- Subclasses cannot see private members of parent class
  - Is this a concern?
- "Specialization interface": in what ways can subclasses tweak the behavior of a parent?
  - Another layer of **encapsulation**

- `private` ("don't mess with my invariants")
  - Parent class has exclusive responsibility
- `protected` ("I'm trusting you")
  - Derived classes have rights and responsibilities
- `public`
  - The "client interface" is also usable by derived classes

Constructors

- Since some state *could* be private, subclass *must* call a parent class constructor
  - Invoked using `super()`
  - Must be first statement in subclass constructor
- Delegation order: fully construct superclass, then specialize

Overriding

- A subclass method with the same signature as a parent class method will **override** it
  - Whenever that method is invoked on the object, the *subclass* version will be executed
  - Consequence of **dynamic dispatch**
- Impossible for client to request a parent implementation
  - Only subclass impl could know about all the relevant invariants
- Subclass may delegate to its parent's implementation
  - ```
    @Override
    public void move(int r,
        int c) {
      super.move(r, c);
      checkPromotion();
    }
    ```
- No way to prefer "grandparent's" implementation
    ```

OOP terms chart

- extends
- interface / implements
- @override
- public/private/protected
- super

- Interface
- Encapsulation
- Interface/Subtype Polymorphism
- Inheritance
- Compile time reference rule
- Dynamic dispatch

Object

- All classes are a subtype of Object
  - If no extends clause, then Object is the superclass
  - Interfaces implicitly must be implemented by an Object
- Object provides useful universal methods that you may want to override
  - `toString()`
  - `equals()`
  - `hashCode()`

Equality

Referential equality (identity)

- Are two objects the same object?
- Test using ==

Logical equality (state)

- Should two objects be considered equivalent (substitutable)?
- Override `equals()` to define separately from identity
- Danger if class is mutable

Equivalence relations

- Reflexive
  - You equal yourself
- Symmetric
  - If you equal someone, they equal you
- Transitive
  - If you equal someone and they equal someone else, you also equal that someone else

Overriding `.equals()`

```
@Override
public boolean equals(Object other) {
    if (!(other instanceof Point)) {
        return false;
    }
    Point p = (Point) other;
    return x == p.x && y == p.y;
}
```